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GLACIER CAVE OBSERVATIONS ON LLEWELLYN GLACIER, BRITISH COLUMBIA

BY

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ABSTRACT

The aim of this paper is to report some morphological, glaciological and sedimentological observations made in a glacier cave on Llewellyn Glacier, British Columbia. The part of the cave investigated was about 700 metres long. The temperature in the cave was measured and the speleogenesis of the cave is discussed. Finally some suggestions are put forward as to further investigation that might be undertaken.

INTRODUCTION

In many investigations carried out on glaciers there is mention of glacier caves but particular details of long caves appear in only a few articles written by speleologists (e. g. Peterson & McKenzie 1968, McKenzie 1970, Halliday & Anderson 1970a and 1970b). The reason for this has obviously been that most of the tunnels have been drainage ways formed by meltwater at the termini of the glaciers: consequently it has been impossible to penetrate the tunnels.

Caves in and under glaciers are of special interest to glaciologists and geomorphologists since they present a new perspective that helps to explain how eskers, for example, are formed (cf. e. g. Stokes 1958).

The author was afforded a rare opportunity to visit glacier caves on Llewellyn Glacier in British Columbia in the course of the 12th Glaciological and Arctic Sciences Institute held in 1971 on the Juneau Icefield (Fig. 1). The observations made during the visit are reported in the following article. The possible origin of the cave is also discussed and the results obtained from the observations are compared with information available from earlier reports.

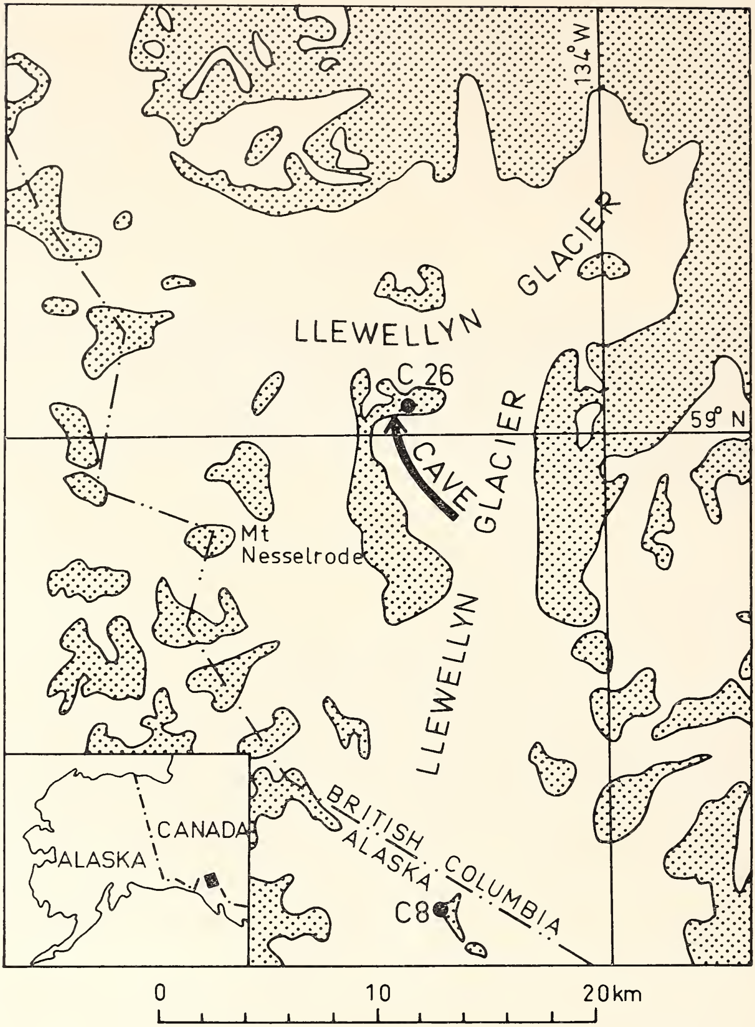

Fig. 1. General location of the glacier cave.

DESCRIPTION OF GLACIER CAVE

The cave is situated on the edge of Llewellyn Glacier near Camp 26 (approx. 59°N, 134°10'W, about 1 650 m a. s. l.) where there is a rocky pocket which is not completely filled by the glacier (Fig. 1). Between

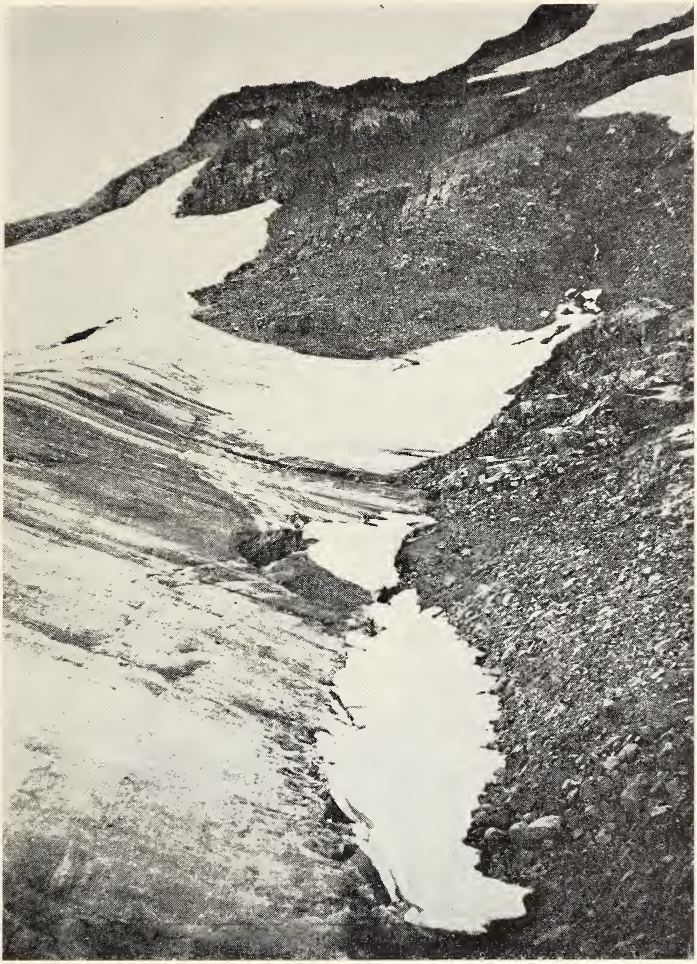

Fig. 2. General view from the edge of the glacier looking SW. Entrance to cave can be seen at centre. Photographs taken by the author. August 21, 1971.

the rock and the edge of the glacier there has earlier been a marginal lake very similar to the Ice Cave Lake described by Maag (1969, p. 20—27) on Axel Heiberg Island, Arctic Canada. Even though the cave lies within the glacier ablation zone several metres of snow, which had not melted even by the end of August, lay in the hollow of rock sheltered from the effects of wind and sun (Fig. 2). The roof of the entrance to the cave consisted of snow for a few metres (Fig. 3).

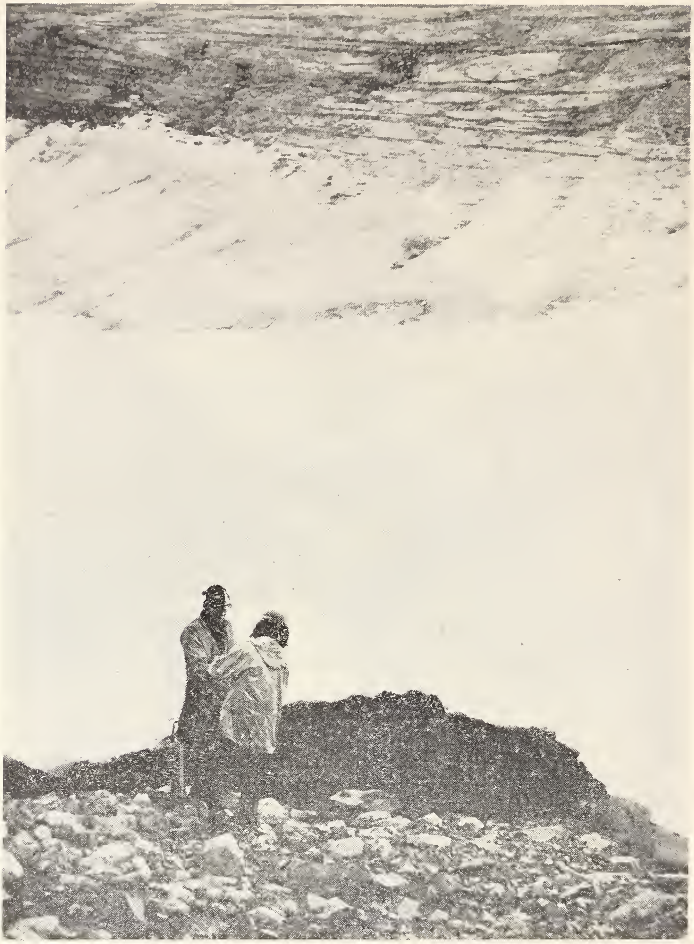

Fig. 3. Entrance to the cave. August 21, 1971.

The cave sloped downwards rather steeply at an angle of 20—25° under the glacier for a distance of some 150 metres. Then the main part of the cave made a turn, followed the direction of the glacier more or less and wound its way onwards. In places the cave rose and approached the edge of the glacier while at others it penetrated more deeply into the glacier (Fig. 4). Altogether some 700 metres of the cave were investigated. The main part of the cave continued but became rather small and low.

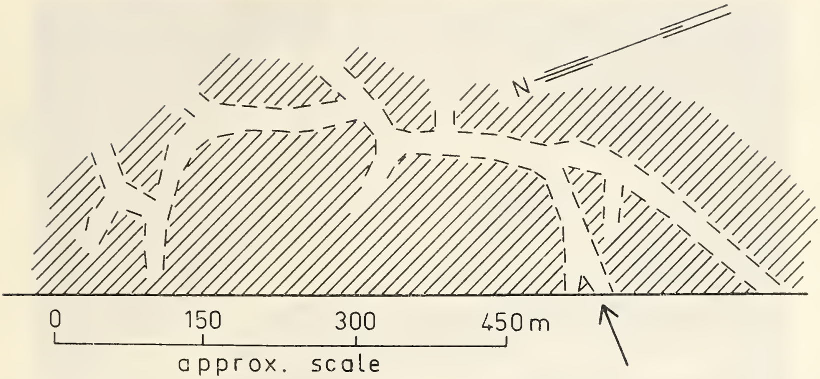

Fig. 4. Diagram showing itinerary through the cave: the diagram was drawn using compass directions and counting the number of steps taken. Arrow indicates entrance. Breadth of the cave is not drawn to scale.

The main cave had several side galleries some of which came from the edge of the glacier and proceeded deeper into the glacier. The openings of these galleries, however, were so low that it was impossible to get out of the cave system via these galleries. Along a number of these side galleries there flowed meltwater from the edge of the glacier. Two active glacier moulins (mills) had bored their way through the roof of the cave bringing water from the surface of the glacier (Fig. 5). The openings of several old, dead moulins which had dried up were also encountered (Fig. 7). The main cave was for the most part dry.

The height of the cave in the section investigated varied from 0.5 to 6 m. The largest chamber was situated just inside the entrance to the cave (Fig. 6). In general there were large chambers where it was possible to walk upright followed by short, low, narrow sections. In the chambers between the arms of the cave there were the eroded remains of ice pillars similar to those reported by Halliday & Anderson (1970a, Plate XV A) in Paradise Ice Cave, Washington State.

The shape of the cave varied considerably. At many points it was possible to see ridges in the walls caused by meltwater action (Fig. 7). In places the cave was a regular semicircular vault in shape. The form of the cave floor and its gradient had clearly exerted an influence on the shape of the cave (Fig. 7). The floor was in places very sloping (as much as 55°). In places at the edge of the cave meltwater had furrowed a low groove through which water flowed.

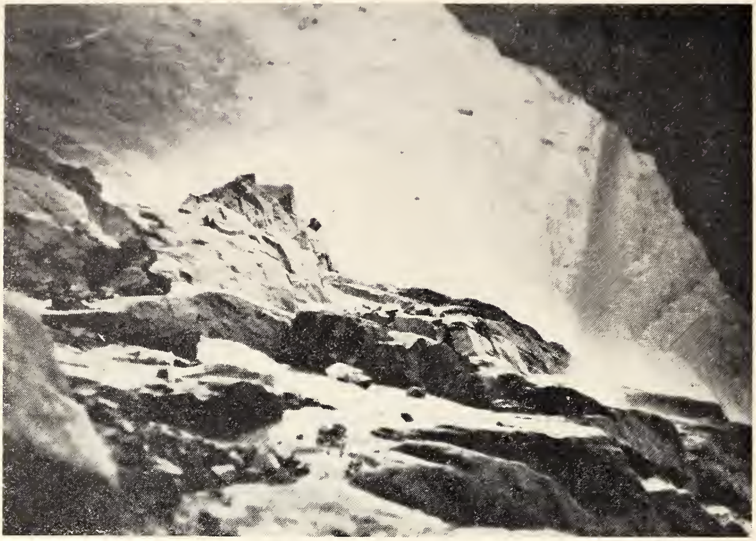

Fig. 5. Meltwater from the surface of the glacier entering the cave through a glacier moulin (mill). Bedrock can be seen on the floor of the cave. The man at left centre of the picture gives an idea of the scale. August 21, 1971.

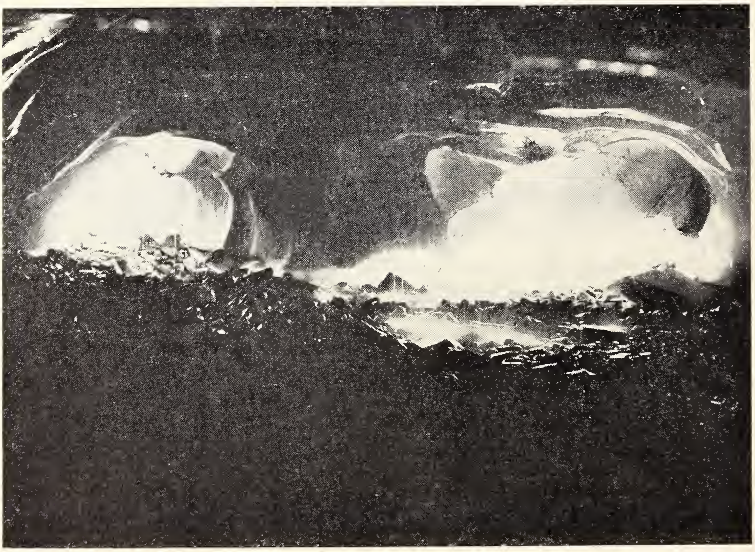

Fig. 6. View of the largest chamber looking towards the entrances. There is water dripping from the roof of the cave. August 21, 1971.

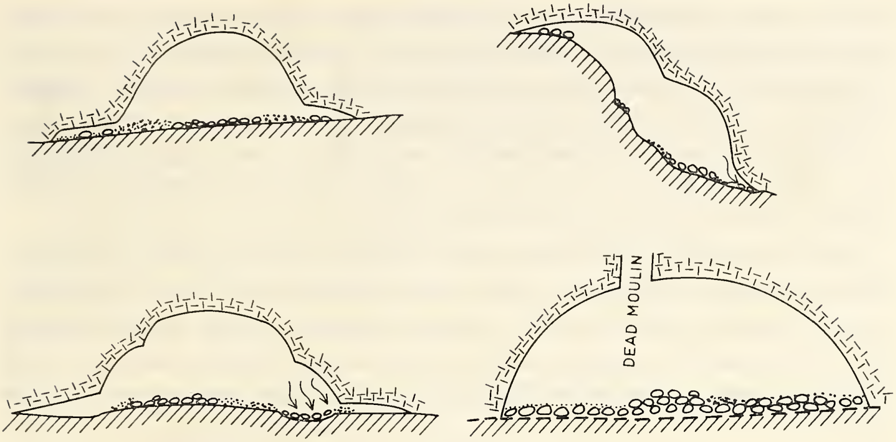

Fig. 7. Diagrammatic cross-sections of the cave not drawn to scale. Arrows show flowing meltwater.

The floor of the cave was for the most part covered by different sediments. Most of the floor was made up of washed boulders and stones. These were often covered by a layer of silt between 0.5 and 1 cm thick. In places sand bars some 20—50 cm high had formed. Only at a few points was the floor of the cave formed of bare ice. At the edge of the ice there were small sand forms that resembled kame terraces.

At the site of glacier moulins there was a thin layer of ice on the cave floor but no stalactites or stalagmites of ice were found (cf. Halliday & Anderson 1970a, p. 57; 1970b, p. 26—27; McKenzie 1970, p. 2). The cave was obviously too warm in August for these to form (cf. Halliday & Anderson 1970a, p. 57; 1970b, p. 26—27). The ambient air temperature outside at the time of entering the cave was +3°C and on returning from the cave +3.5°C. At the deepest parts of the cave, roughly 60 m beneath the surface of the glacier, the air temperature was +0.5°C and in other parts of the cave it varied between 1.5 and 2.5°C.

At the edge of the glacier the cave floor was made up of roches moutonnées, in which the striae ran in two directions, S30°W → N30°E and SW → NE. These correspond roughly to general direction of flow of the Llewellyn Glacier at that spot nowadays.

The roof and walls of the cave were covered with cup-like cavities caused by melting (cf. Halliday & Anderson 1970a, Plate XIV B and

XV A). The material of the walls and roof was blue-white and blue ice and several crystals 5 cm in diameter were encountered. In places there were dirty layers in the structure of the ice and also thin fissures which had frozen over again. In general, however, the ice was clean.

The glacier was relatively static and only at two points where the rock came into contact with the ice was broken ice observed: this ice formed a layer about two centimetres thick.

As for the light within the cave mention may be made of the fact that the deepest parts of the cave were quite dark and it was necessary to use a electric torch in order to make progress. In the vicinity of the edge of the glacier daylight could be seen through the ice so that it was possible to take photographs of the inside of the cave using long exposure times.

SPELEOGENESIS

The cave had obviously formed originally as the outlet tunnel of an ice-dammed lake through which meltwater from the edge of the glacier had flowed under the glacier. In August 1971 meltwater penetrated the network of caves and tunnels principally from openings which lay farther up the edge of the glacier and from glacier moulins.

The direction of the cave was at many points at right angles to crevasses to be found on the surface of the glacier. However, the winding course of the cave indicates that the cracks may well have played a decisive role in determining the direction of the cave in places at the time of its formation. Glacier moulins are situated near the crevasses. At points where glacier moulins occurred the cave was higher than elsewhere.

It is very difficult to explain the variations in the width of the cave. Originally meltwater shaped the cave and the water may have penetrated under the glacier in stages. Those sections of the tunnel where the water flowed quickly were narrow whereas in the more open chambers succeeding these narrow sections the ice was eaten away by the action of glacier moulins, for example, before the formation proper of the cave took place. Structural differences in the glacier may also have accounted for different melting rates. Where glacier mills formed the melting of the ice would, for instance, have been directed upwards.

The ablation action of warm air (Peterson & McKenzie 1968; Halliday & Anderson 1970a; 1970b; McKenzie 1970) caused the pock-marked appearance of the walls of the cave but it is difficult to say whether this was the cause of the broadening out of the tunnel, especially as sharply defined ridges caused by meltwater action are still visible on the walls of the cave. The thin layer of silt covering almost the whole of the floor of cave is probably an indication that only slowly flowing water has filled the cave recently.

An interesting speleogenetic question is whether the cave was formed from the top downwards or from the bottom upwards. In the former case there must have flowed water inside the glacier which through ablation action directed against the floor of the cave would have eaten away a channel right to the bottom of the glacier. In the latter case, with ablation acting upwards, theories concerning the emptying mechanisms of ice-dammed lakes are brought to mind: the water would then have raised the ice (e.g. Glen 1954). This presupposes, however, that the amount of water in the cave at the time of its formation and its extension outwards increased constantly so that erosion could always be directed against the roof of the cave. In this case there was obviously not enough water in the ice-dammed lake to cause the ice to be lifted. Furthermore, once the water had emptied from the lake, the cave would have ceased to develop any more if there had been any question of the ice being lifted up. The ridges caused by meltwater, which in places are at different levels on opposite walls (Fig. 7), probably indicate that the cave was not at all times filled with water. The cave must therefore obviously have formed from the top downwards. The position of the ridges at different levels may be evidence that several small caves may have become joined together to form a larger one.

DISCUSSION AND SUGGESTIONS

The examination of glacier caves offers glaciologists interested in glacier stratigraphy and ice texture new possibilities. Moreover, from inside such caves it is possible to examine the mechanics of glacier movements and the internal drainage of the glacier. Caves which have formed under natural conditions may also be used as a starting point from which to drive artificial tunnels into the glacier for purposes of research. It is also possible in glacier caves to cast light on problems which are of interest to geomorphologists and sedimentologists.

Changes in such caves brought about by collapse and periodic refreezing are interesting questions which cannot be answered in detail except on the basis of observations made over some considerable period of time.

Glacier caves offer opportunities for investigating the formation of potholes. The amount of running water and the erosion that it causes can be measured inside glacier caves. The observations made and discussed here indicate that the temperature within the cave must be above freezing point when potholes are formed so that water running in glacier moulins does not freeze. Neither must the ice be very thick for then glacier mills do not penetrate very deep into the surface of the ice (cf. Stenborg 1969, fig. 6).

There is every reason to continue investigations on the Llewellyn Glacier cave, and the Juneau Icefield Research Program's permanent base at Camp 26 not far from the cave provide an excellent opportunity for such investigations. As a first step it is necessary to chart the cave and take careful measurements of its dimensions. Such a map would then provide a base for further observations on the cave. With the aid of glacier mills it is easy to determine the glacier's rate of progress even from the surface of the glacier. Charting the cave over a number of years would make it possible to follow the development of the cave and changes in its shape, etc.

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